

BACKGROUND TO THE INVENTION

This invention provides improved closures for use in connection with food or beverages. One application is in relation to closures for wine bottles.

Wine bottles have traditionally been stoppered with corks made from natural cork material. However, this material can be subject to initial flaws, or deteriorate in use, resulting in contamination or spoilage of the wine. For example, oxidation of the wine, due to permeation of oxygen through the cork into the wine, results in vinegar flavour. "Cork taint", due to the presence of trichloro-anisoles (TCA) and other undesirable flavour-active or odour-active compounds in the cork, imparts a musty or mouldy smell and flavour to the wine. Leakage can also be a problem. Furthermore, cork is a relatively expensive material, as most supplies still come from Portugal.

None of the alternatives to natural corks proposed to date have been entirely satisfactory.

Synthetic "corks" and screw-cap stoppers have been used in the wine industry, but have not yet been tested adequately over the prolonged storage periods of quality red wines. There is some indication, however, that synthetic "corks" may impart flat flavours to wines. Furthermore, there is considerable consumer resistance to use of synthetic "corks" and screw-cap stoppers, particularly for quality wines. A further

disadvantage is that synthetic "corks" are generally far more difficult to remove, using a hand-operated corkscrew, than natural corks.

Accordingly, there have been numerous attempts to improve on natural cork stoppers, by coating or impregnating them.

The first cork coatings were simply lubricants such as paraffin and Vaseline. These merely ensured that the cork was easier to insert into the bottle and later remove, without disintegration. The other problems associated with cork stoppers were not addressed.

Currently, materials used in surface treatment of corks include oils and silicone resins, emulsions of various formulations, as well as some synthetic coatings. These coatings do prevent leakage of the wine, but do not provide a barrier against taint and oxidation.

Many of these coatings also present problems with the coating coming off the cork and leaving an oily layer on the wine surface.

Hybrid corks have been moulded from natural cork and synthetic cork cells made from a synthetic polymer. The synthetic cells fill the gaps between the cork cells, and a binding agent (such as polyurethane) is used to bind the cells together. However, hybrid corks have to date proved unsatisfactory, as they often leak and can disintegrate and be difficult to extract from a bottle.

The present invention provides an improved closure having a surface coating or diffusion layer comprising an appropriate polymer. This coating or diffusion layer has many properties which are of benefit when used (for example) in relation to corks (either natural or synthetic) for wine bottles. The coating or diffusion layer limits oxygen permeability, inhibits or prevents the diffusion of trichloro-anisoles (TCA) and other flavour-active or odour-active compounds from the cork to the alcoholic beverage, adheres strongly to the cork and/or penetrates into the surface of the cork, is sufficiently flexible to be capable of withstanding compression and decompression during the corking process, enables the coated cork to be readily extracted from the bottle, reduces or prevents wine leakage, is resistant to sulphur dioxide, and has long life under alcoholic beverage conditions.

These coatings or diffusion layers are also applicable to substrates other than cork (eg packaging and wrapping materials) which are in contact with food products or beverages.

SUMMARY OF THE INVENTION

According to the present invention, an appropriate polymer, having functional groups which are reactive with a substrate and with one or more flavour-active or odour-active compounds (commonly known as taint compounds), e.g. TCA, is applied as a surface coating or diffusion layer to said substrate, said substrate being for use in contact with food products or beverages. The substrate may, for example, be a bottle closure (such as

a cork), packaging and wrapping materials (such as packaging for cheese), or a bottle or other container.

In a first aspect, the present invention provides a method for producing a coating or diffusion layer on a substrate (eg a cork) for use in contact with a food product or beverage, said coating or diffusion layer preventing or inhibiting passage therethrough (eg from a cork to an alcoholic beverage) of flavour-active or odour-active compounds, and said method comprising applying to the surface of said substrate an effective amount of a reactive polymer, said reactive polymer being a polymeric material comprising first functional groups which react with at least one flavour-active or odour-active compound and second functional groups (which may be the same as or different from said first functional groups) which react with said substrate.

In a second aspect, the present invention provides a coated substrate, and in particular a coated natural or synthetic cork, produced according to that method.

As mentioned above, the polymer is selected so as to be reactive with both the substrate and with at least one flavour-active or odour-active compound (eg TCA). Accordingly, the polymer may comprise first functional groups which can react with the TCA or other flavour-active or odour-active compound, thus anchoring it to the polymer, and second functional groups (which may be the same as or different from the first functional groups) which can react with the substrate. The interaction may take the form of covalent bonding, hydrogen bonding, dipole-dipole interaction, polar

interaction, ionic bonding, electrostatic forces or acid-base interaction, but not van der Waals forces. The polymer may interact using one or a combination of the above.

As already mentioned, the polymer has functional groups which are reactive with a substrate and with one or more flavour-active or odour-active compounds.

Accordingly, the polymer coating or diffusion layer, in addition to acting as a partial physical barrier to the passage of gases (eg oxygen) and flavour-active or odour-active compounds, also forms a chemical barrier to the passage of such compounds. In particular, the polymer of the coating or diffusion layer will be reactive with any flavour-active or odour-active compounds in a cork, to prevent them from migrating from the cork into an alcoholic beverage. The polymer is also selected to be sufficiently flexible for its proposed use (eg to withstand compression and decompression during the corking process, if the substrate is a cork). Furthermore, if the substrate is a cork, the polymer coating or diffusion layer must enable the coated cork to be readily extracted from the bottle, prevent wine leakage, and have long life under alcoholic beverage conditions. Preferably, the polymer coating or diffusion layer will also be resistant to sulphur dioxide and changes in pH.

DETAILED DESCRIPTION OF THE INVENTION

Suitable polymers and copolymers which may be used include those described in the following references:

J. Wen, G. L. Wilkes, Polymer Bulletin, 1996, 37, 51-57

J. Hazziza-Laskar, G. Helary, G. Sauvet, J. Appl. Polym. Sci., 1995, 58, 77-84

Tezuka et. al., *Macromolecules*, 1995, 28(24), 8251-8258

P. Schofield, C. Cohen, C. K. Ober, *Polymer Gels & Networks*, 1998, 6(3-4), 291-300

T. Furuzuno, K. Seki, A. Kishida, T. Ohshige, K. Waki, I. Maruyama, M. Akashi, *J. Appl. Polym. Sci.*, 1996, 59, 1059-1065

D. Spridon, L. Panaitescu, D. Ursu, C. V. Uglea, I. Popa, R. M. Ottenbrite, *Polymer International*, 1997, 43, 175-181

J. C. Schmidhauser, K. L. Longley, *J. Appl. Polym. Sci.*, 1990, 39, 2083-2096

L. Lestel, H. Cheradame, S. Boileau, *Polymer*, 1990, 31, 1154-1158

G. E. Hahn, K. D. Klein, I. Yilgor, C. Could; In Silicone-Containing Polymers
Editor, R.G. Jones; The Royal Society of Chemistry: Cambridge, UK; 1995; pp 81-87

M. A. Sherman, J. P. Kennedy, *J. Appl. Polym. Sci.*, 1998, 30, 1891-1899

Examples are:

polyurethanes and copolymers and ionomers

terephthalate copolymers

polyethylene vinyl alcohol

(vinylidene) copolymers

epoxy polymers and copolymers

polyamides and amide copolymers

styrene-acrylonitrile (SAN)/acrylonitrile-butadiene-styrene (ABS) copolymers

poly (methacrylic acid) and copolymers

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poly (methyl) methacrylate and copolymers

Bisphenol copolymers

Bisphenol A (BPA) – epichlorohydrin polymers

cellulose derivatives and copolymers

polyacetal

polyvinylacetate (PVA) copolymers

monofunctionalised, difunctionalised and polyfunctionalised silanes (eg comprising amino or thiol groups) and copolymers

monofunctionalised, difunctionalised and polyfunctionalised siloxanes and siloxane copolymers, eg comprising polyethyleneglycol (PEG), isoprene,

butadiene, lactone, amino, terephthalate, amino acid, heterocyclic, hydride (SiH), thiol or epoxy functionalities

functionalised and unfunctionalised polysilsesquioxanes,

examples of which are disclosed in the following references:

Feher, F. J and Budzichowski, T.A., J.

Organometal. Chem., 379:33-40, 1989

Feher, F.J., Wyndham, K.D., Soulivong, D. and

Nguyen, F., J. Chem. Soc. Dalton Trans., 1491-1497, 1999

Feher, F.J., Schab, J.J., Soulivong, D. and Ziller, J.W.,

Main Group Chemistry, 2:123-132, 1977.

Polyethylene vinyl alcohol, functionalised silanes and functionalised siloxanes (eg amino-, epoxy- or hydride-substituted siloxanes) have been found to be particularly suitable.

Modifications of the polymers may be necessary to improve resistance to reactions with various components of the food product or beverage (eg wine).

The polymer coatings and diffusion layers of the present invention may be used in conjunction with lubricants, such as paraffin or Vaseline, to make the coated cork easier to insert into a bottle and later remove.

The method of applying the polymer to the substrate will be dependent on the nature of the polymer and of the substrate, and will include such conventional processes as film formation, adsorption from solution, reactive-adhesion to cork, melt polymer application (eg thermoforming, vacuum forming and plasma polymerisation), UV curing and Corona discharge processes. The polymers may also be components of multilayer laminate structures.

Preferably, the substrate (eg cork) is prewashed with a solution (eg ethanol, water or a mixture of ethanol and water) and then dried before coating, to remove any surface contamination.

The following examples form an overview of some of the technologies which may be used. These examples are illustrative, but not restrictive, of the present invention.

DESCRIPTION OF THE DRAWINGS

FIG 1 illustrates the reactivity of polyethyleneglycol (PEG) with TCA, and is a graph of residual TCA (in mg) versus PEG (in mg), as measured by HPLC (see Example 1).

FIG's 2A-C are the results of Scanning Electrode Microscopy (SEM) of the coating of Example 5.

FIG's 3A-D are the results of SEM of the coating of Example 6.

REACTIVITY TESTS

HPLC (High Performance Liquid Chromatography) Method

The instrument used for these experiments was a Waters 2690 Separations Module with a Waters HPLC column (Nova-Pak® C18 60Å 4µm 3.9 x 150mm HPLC column) and a Waters 996 Photodiode Array Detector. The system was run with Millennium³² software.

System settings: Temperature: 24.6°C

Flow rate: 1.000mL/min

Mobile phase: 90% Methanol 10% Milli-Q water

Pressure: Pressure limit 4000 psi

Wavelength: 230nm

Three injections with an injection volume of 10 μ L per vial were made. Each run was for 8.00 minutes. A standard curve was obtained for TCA concentrations ranging from 0.07-100 mg/L prepared in methanol.

Example 1: Polyethyleneglycol

Column Preparation

A 2mL pasteur pipette was plugged with glass wool and filled with the required weight of polyethyleneglycol (PEG; MW 10000). Four different columns were prepared in this manner, containing PEG with weights of 46mg, 92mg, 138mg and 184mg.

TCA was dissolved in n-Heptane (1mg/L). 1mL of this solution was eluted through the prepared column. The heptane evaporated, the residue was diluted with 1mL of methanol and the sample was then injected into the HPLC. The results indicated that, as the amount of PEG increased, more TCA was retained.

FIG 1 is a graph of residual TCA (in mg) versus PEG (in mg).

Control Sample

A control sample was necessary to ensure that there was no interaction between the TCA and the glass wool.

1mL of a 1mg/L solution of TCA in methanol was eluted through a column (2mL pasteur pipette) containing untreated glass wool packed 2.5cm high. HPLC was carried out on the eluant to determine the concentration of TCA. 0.999mg/L was detected, which was only 0.001mg/L deviation from the original concentration. This indicated that there was no interaction between the glass wool and the TCA.

Example 2: Amino functional group

Method

2mL of aminopropyltriethoxysilane was added to 98mL of a 95% (v/v) ethanol / water mixture. Glass wool was immersed in this solution overnight, rinsed with ethanol and dried in an oven at 100°C for 20 minutes. The glass wool was analysed by Diffuse Reflectance Fourier Transform Infrared Spectroscopy (DRIFT) to ensure that the silane had attached itself to the glass surface.

A pasteur pipette, used as a small column, was packed with the above glass wool, 2.5cm high.

1mL of 1mg/L TCA in methanol was eluted through the column and washed with methanol. The eluant was analysed by HPLC for TCA. No TCA was detected.

Example 3: Epoxy functional group**Method**

2mL of Glycidoxypyrpyltrimethoxysilane was added to 98mL of a 95% (v/v) ethanol / water mixture. Glass wool was immersed in this solution overnight, rinsed with ethanol and dried in an oven at 100°C for 20 minutes. The glass wool was analysed by DRIFT to ensure that the silane had attached itself to the glass surface.

A pasteur pipette, used as a small column, was packed with the above glass wool, 2.5cm high.

1mL of 1mg/L TCA in methanol was eluted through the column and washed with methanol. The eluant was analysed by HPLC for TCA. No TCA was detected.

Example 4: Methacryl functional group**Method**

2mL of [3-(Methacryloyloxy)ethyl]trimethoxysilane was added to 98mL of a 95% (v/v) ethanol / water mixture. Glass wool was immersed in this solution overnight, rinsed with ethanol and dried in an oven at 100°C for 20 minutes. The glass wool was analysed by DRIFT to ensure that the silane had attached itself to the glass surface.

A pasteur pipette, used as a small column, was packed with the above glass wool, 2.5cm high.

1mL of 1mg/L TCA in methanol was eluted through the column and washed with methanol. The eluant was analysed by HPLC for TCA. No TCA was detected.

SENSORY EVALUATION TESTS

Corks were spiked with TCA by soaking 100 corks in 1.5 litres of a 100mg/L solution of TCA in absolute ethanol for 24 hours. The corks were then removed from the solution and allowed to dry in a 40°C oven for 24 hours before being submitted for sensory evaluation to ensure that the corks have TCA odours. These corks were then coated with the coatings described below and sent for sensory evaluation.

Coated TCA spiked corks were immersed in approximately 150mL of white wine for 24 hours. The wine was evaluated for unacceptable odours by a team of experts, being a group of no less than three qualified trained sensory evaluators. The samples were given a rating of between 1 and 4. A rating 1 indicated a slight odour, rating 2 a moderate odour, rating 3 a strong odour and rating 4 a very strong odour. A rating of 2 or less was acceptable. The sensory evaluation tests related primarily to TCA odours, which were indicative of likely problems relating to undesirable flavour- and odour-active compounds.

COATINGS

A TCA spiked cork and a non-TCA cork were coated with the coatings described below and subjected to sensory evaluation.

Example 5: Two Dip process (Epoxy silicone / Aminopropyltriethoxysilane)

Corks were dipped into an epoxy silicone solution and then into a 0.1% solution of Aminopropyltriethoxysilane in water. The coating was allowed to cure at 40°C for 1 hour.

Sensory evaluation tests gave a rating of 2 or less. Scanning Electrode Microscopy (SEM) showed an obvious smooth layer of coating (Fig 2A). The coating was undisturbed after a compression test (Fig 2B) and there was no visible deterioration of the coating even after being immersed in white wine for 24 hours (Fig 2C).

Example 6: Polyvinylacetate/Polymethylhydrogen Siloxane Emulsion

The coating consisted of a mixture of 75mL of Polyvinylacetate emulsion (PVA) and 25mL of Polymethylhydrogen siloxane emulsion. 100 corks were placed into a tumbler and 20mL of the coating was distributed casually over the corks. The corks were tumbled, to evenly distribute and dry the coating, for 1 hour at 40°C.

Sensory evaluation and gas Chromatography/Mass Spectroscopy (GC/MS) results showed that no TCA or other undesirable odours were detected. In particular, sensory evaluation tests gave a rating of 2 or less.

The SEM showed a visible uniform coating on the surface of the cork (FIG 3A). The coating was also visible in cracks on the surface of the cork (FIG 3B). Analysis of the coating after it had been immersed in white wine for 24 hours showed that the coating was still present and intact (FIG 3C). After compression in a commercial hand corking device, the coating still formed a continuous layer (FIG 3D).

Example 7 : Polyurethane

A mixture of 1,3-Bis(aminopropyl)tetramethyldisiloxane (3g, 0.012mol) and caprolactone (4.1g, 0.036mol) was heated to 75°C under nitrogen before the catalyst, stannous octoate (0.1mL), was added. The mixture was refluxed for 2 hours at 75°C before the temperature was raised to 140°C for a further 1.5 hours. The product was then allowed to cool.

A mixture of the above product (7g, 0.012mol), dimethylolpropionic acid (0.8g, 5.95×10^{-3} mol), hexamethylenediisocyanate (3g, 0.018mol), acetone (20mL) and dibutyltin dilaurate (0.1mL) was stirred under nitrogen at 35°C for 15 minutes and then allowed to cool. Triethylamine (1mL) was added and stirred continuously for 30 minutes, before carefully adding 30mL of distilled water. The acetone was removed *in vacuo* to give the water-dispersed polyurethane.

Corks were dipped into this coating and allowed to cure in an oven at 40°C for 24 hours.

Sensory evaluation tests gave a rating of 2 or less.

Example 8: Polyvinylidene Chloride / Polymethylhydrogen Siloxane Emulsion

The cork was dipped into a solution consisting of 75% Polyvinylidene chloride and 25% polymethylhydrogen siloxane emulsion. The coating was then cured in an oven at 38°C for 1 hour.

Sensory evaluation tests gave a rating of 2 or less.

Example 9: Mercapto Silicone Emulsion

A cork was dipped in a solution of mercapto silicone emulsion and was submitted for sensory evaluation.

Sensory evaluation tests gave a rating of 2 or less.

Example 10: Poly Acrylate / Methacrylate

A cork was dipped into a solution of 46% acrylic methacrylic acid ester in water and then allowed to dry in a 40°C oven overnight.

Sensory evaluation tests gave a rating of 2 or less.

WASHING PROCEDURE

Corks can be rinsed or soaked with hot or cold water, alcohol, or a mixture of both water and alcohol, before the coating is applied. This reduces the occurrence of taint and other unwanted odours by washing away any taint compounds already on the surface of the cork. It is thought that any surface taint could mix with the coating during the coating process and remain on the surface of the coating, thus contributing to, rather than preventing, the taint problem. Accordingly, it is preferable to carry out a washing procedure, eg as in Example A, B, C or D below, prior to coating corks. The corks are then dried, eg in an oven at 40°C for 24 hours, prior to being coated.

Example A

Corks spiked with 100mg/L of TCA in absolute ethanol were arranged in a single layer and passed through streams of hot water for 30 seconds and allowed to dry.

Sensory evaluation tests gave a rating of 2 or less.

Example B

Corks spiked with 100mg/L of TCA in absolute ethanol were arranged in a single layer and passed through streams of liquid containing cold water and absolute ethanol and allowed to dry.

Sensory evaluation tests gave a rating of 2 or less.

Example C

Corks spiked with 100mg/L of TCA in absolute ethanol were completely immersed in a solution of hot water for 30 minutes and allowed to dry.

Sensory evaluation tests gave a rating of 2 or less.

Example D

Corks spiked with 100mg/L of TCA in absolute ethanol were completely immersed in a solution containing a mixture of cold water and absolute ethanol.

Sensory evaluation tests gave a rating of 2 or less.

METHODS OF APPLICATION**Dip Coating**

The simplest application method is dip coating, involving a container filled with the coating formulation into which the substrate (such as a cork) is immersed and then withdrawn.

A typical dip coating unit consists of a bath, filled with the coating formulation, and a mechanism on which the substrate is mounted for immersion and withdrawal. It is often necessary to circulate and filter the coating to maintain a homogeneous mixture. A fixing mechanism must be designed to ensure the proper orientation of the substrate during immersion into and withdrawal from the fluid.

Spray Coating

In contrast to dip coating, spray coating operations are much less efficient and much more complicated, as well as being relatively more expensive. Precise control over the spray area is difficult so that masking of the substrate may be required. The advantages offered by these systems (eg fast application time, very uniform coating thicknesses, and the ability to apply uniform coatings to irregularly shaped objects) may, however, outweigh the drawbacks.

In a spray coating operation, the fluid is atomised into fine droplets for application to the substrate. The size of the droplets formed during atomisation can be controlled by such properties as fluid flow, fluid pressure, air pressure, solution viscosity, and surface tension. A number of different nozzle designs are used in industry, such as compressed air spray nozzles, airless spray nozzles, and hot spray systems.

Slot and Curtain Coating

Slot coating and curtain coating are more appropriate techniques for a continuous operation. The methods involve a stationary die, which delivers a layer of coating onto a substrate moving beneath it. The difference between the methods is in the way that the coating is transferred from the die to the moving substrate. The coating is spread by the slot method when the die slot is close to the substrate; but changing the orientation of the die slot relative to the conveyor and allowing the formulation to cascade is referred to as curtain coating.

Multiple slots in the die face or converging feed to a single slot can produce multilayer coatings.

Roll Coating

Roll coating is another method used in continuous manufacturing operations primarily for coating films. A substrate is fed between two rotating cylinders, while simultaneously directing the coating into the space between the cylinders. Formulation viscosity, speed of the substrate, coating flow rate, and distance between the rolls all contribute to coating thickness and uniformity. Although these systems are limited in the types of substrate that can be coated, they can rapidly produce a very uniform product.

METHODS OF CURING

Thermal Cure

One of the most common methods for initiating the cross-linking of a polymer is by heating, and ovens can be incorporated into batch and continuous-mode systems. The main disadvantage in thermal curing is the wasted thermal energy when only a small amount of the applied energy is transferred to the molecules. It can also be difficult to maintain a uniform temperature throughout the oven, so that curing may be uneven.

Ultraviolet (UV) Cure

One of the most popular techniques used to initiate cross-linking is irradiation by ultraviolet light. It can be a more rapid process than thermal curing, sometimes taking

less than a second to act. Very little heat is generated during the exposure, which can often be carried out at room temperature.

Electron Beam Cure

Electron beam (E-beam) radiation shares the same benefits as UV radiation, without the need for a photoinitiation. The exposure forms free radicals that cause the chain reaction.

Gamma-Radiation Cure

Yet another type of irradiation that is rapid at ambient temperatures is γ -radiation cure. Cycle times for γ -ray systems can be longer than for E-beam, at least for conventional polymer matrices, but for curing hydrophilic coatings this does not present a problem.

ADDITIONAL TECHNOLOGIES

Plasma Polymerisation

Thin polymer films can be deposited onto various substrates through the use of plasma polymerisation. A plasma is generated by means of electron excitation, with a gas mixture and an organic monomer. These thin films can be between a few hundred angstroms to a micrometre in thickness. Cross-linking density is usually greater than in conventionally applied coatings, and thin films exhibiting good adhesion can be laid down on virtually any type of substrate.

Surface Grafting

Surface grafting techniques incorporate some of the same general concepts as coating and curing operations but may be more appropriate where exceptionally thin surface layers are desired. Points that distinguish surface grafting from "wet" coating operations are related mainly to the formation of the modified surface layer and the general molecular structures that result. In conventional coatings, a continuous phase is formed by the reactions of the monomeric or polymeric ingredients, and is adhered to the substrate surface through secondary molecular interactions such as hydrogen bonding, London dispersive forces or acid-base interactions. Primary covalent bonding is also possible if the substrate has been pre-treated with molecular groups. In surface grafting however, the monomeric (or polymeric with reactive end groups) components react directly with a polymeric substrate. Various forms of radiation, such as UV, electron beam, and γ -rays, may be used to cause the formation of peroxide groups on the polymer surface. These are unstable so decompose, and cause initiation of polymerisation in the process.

While the present invention has been described in terms of preferred embodiments in order to facilitate better understanding of the invention, it should be appreciated that various modifications can be made without departing from the principles of the invention. Therefore, the invention should be understood to include all such modifications within its scope.